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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

OPTICS RESEARCH

SEMIANNUAL TECHNICAL SUMMARY REPORT
TO THE
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

1 JANUARY – 30 JUNE 1976

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LEXINGTON MASSACHUSETTS

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ABSTRACT

This report covers work of the Optics Division at Lincoln Laboratory for the period 1 January through 30 June 1976. The topics covered are laser technology and propagation and pollution studies.

Additional information on the optics program may be found in the ARPA/STO Program Semiannual Technical Summary Reports to the Defense Advanced Research Projects Agency.

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C(14) O2(16)

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I. LASER TECHNOLOGY

An experimental series is in progress to investigate the effects of pulse shape and pulse length on enhanced thermal coupling to metallic surfaces. Pulse lengths of 5, 10, and 25 μsec are being used. The magnitude of the gain-switched spike is being varied for each pulse length.

A three-week experimental effort has been scheduled at Boeing Aerospace Company to study long-pulse breakdown at HF laser wavelengths (2.8 μm).

We obtained one TEM_{00q} mode operation in all four branches of the $00^01 - \{10^00, 02^00\}_I$ and $00^01 - \{10^00, 02^00\}_{II}$ vibrational bands and also in the $01^11 - 11^10$ "hot band" of a $^{14}C^{16}O_2$ laser. The transition frequencies were determined with spectrometer accuracy.*

II. POLLUTION STUDIES

We have applied a new type of widely tunable semiconductor diode laser to our pollution monitoring system which can then permit sequential monitoring of many pollutant gases with a single device. Frequency tuning range of 300 cm^{-1} is possible by adjusting the closed-cycle refrigerator temperature from 15 to 100°K. Important pollutants such as ammonia, ethylene, and ozone have been studied with this advanced instrumentation.†

Both fundamental laboratory spectroscopic measurements and long-path field monitoring should be benefited significantly with this new development.†

* This paragraph describes the work performed at Lincoln Laboratory with sponsorship in part by the Defense Advanced Research Projects Agency and in part by the U.S. Energy Research Development Administration.

† These paragraphs describe the work performed at Lincoln Laboratory under the sponsorship of the National Science Foundation (Research Applied to National Needs), with partial support from the U.S. Environmental Protection Agency.

REPORTS ON OPTICS RESEARCH

1 January through 30 June 1976

PUBLISHED REPORTS

Journal Articles

JA No.			
4230	Infrared Spectroscopy with Tunable Lasers	E. D. Hinkley K. W. Nill* F. A. Blum	Chapter 2 in Laser Spectroscopy of Atoms and Molecules, H. Walther, Editor, a volume in the series Current Topics in Physics (Springer-Verlag Publishers, Heidelberg, Germany, 1976)
4558	Fraunhofer Diffraction Due to an Elliptic Annulus	L. C. Bradley	J. Opt. Soc. Am. 66, No. 2, 190 (February 1976)
4595	Large-Spot Thermal Coupling of CO_2 Laser Radiation to Metallic Surfaces	S. Marcus J. E. Lowder D. L. Mooney	J. Appl. Phys. 47, No. 7, 2966 (July 1976)
4602	Long-Path Monitoring: Advanced Instrumentation with a Tunable Diode Laser	E. D. Hinkley R. T. Ku K. W. Nill* J. F. Butler*	Appl. Opt. 15, No. 7, 1653-1655 (July 1976)

Meeting Speeches

MS No.			
4072	Laser Spectroscopic Instrumentation and Techniques: Long-Path Monitoring by Resonance Absorption	E. D. Hinkley	Opt. Quantum Electron. 8, No. 2, 155-167 (March 1976)
4092A	Coherent Infrared Radar	R. H. Kingston L. J. Sullivan	Proc. 31st Technical Meeting, Avionics Panel of AGARD, The Hague, Netherlands, 14-18 June 1976

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.			
4515	Techniques for Detection of Molecular Pollutants by Absorption of Laser Radiation	E. D. Hinkley R. T. Ku P. L. Kelley	Accepted for publication in Laser Monitoring of the Atmosphere (Springer-Verlag Publishers, Heidelberg, Germany)

* Author not at Lincoln Laboratory.

JA No.			
4582	Identification of the SF_6 Transitions Pumped by a CO_2 Laser	R. S. McDowell* H. W. Galbraith* B. J. Krohn* C. D. Cantrell* E. D. Hinkley	Accepted by Opt. Commun.

Meeting Speeches†

MS No.			
4092B	Coherent Infrared Radar	R. H. Kingston	Seminar, Harry Diamond Laboratories, Washington, D. C., 12 March 1976
4092C	Coherent Infrared Radar	L. J. Sullivan	Eighth Semiannual National Science Foundation Meeting on Optical Communication, M.I.T., 8-9 June 1976
4202	Phase Compensation and its Limits	L. C. Bradley	6th Winter Colloquium on Quantum Electronics, Steamboat Springs, Colorado, 1-4 February 1976
4219	Shared Apertures in Tracking Turbulence-Induced Wave-Front Tilt Errors	D. P. Greenwood	Conference on Laser and Electro-Optical Systems, San Diego, 25-27 May 1976
4323	Absolute Frequency Calibration of the CO_2 Isotope Laser Transitions	C. Freed R. G. O'Donnell A. H. M. Ross*	Conference on Precision Electromagnetic Measurements, Boulder, Colorado, 28 June – 1 July 1976

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

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I. LASER TECHNOLOGY AND PROPAGATION

A. LASER EFFECTS

1. Effect of Pulse Shape and Pulse Length on Enhanced Thermal Coupling to Metals

An experimental series is in progress to investigate the effects of pulse shape and pulse length on enhanced thermal coupling of pulsed 10.6-μm radiation to metallic surfaces. The Lincoln Laboratory 500-J CO_2 laser configured as an off-axis, unstable resonator is being used for the tests. Measurements are being made at pulse lengths of 5, 10, and 25 μsec. For each pulse length, the gain-switched spike to average energy ratio is set at the "normal" value of 7:1 or, through the use of two-level pulse-forming networks, at a value of approximately 2 or 3:1. The thermal coupling is being measured using both calorimetric and time-resolved, fast surface thermocouple techniques.

Beam diagnostics include shot-by-shot measurements of the power (pulse shape), total energy, and spatial distribution. Plasma diagnostics include streak photography to measure the rate of plasma expansion and a measurement of the plasma ignition time relative to the arrival of the radiation pulse at the target surface.

The experiments are currently in progress, and the results will be reported in detail in the next Optics Research Report.

S. K. Manlief

2. Long-Pulse HF Laser Breakdown Experiment

A three-week experimental effort has been scheduled at Boeing Aerospace Company to study long-pulse breakdown at HF laser wavelengths (2.8 μm). The primary objectives of the experiment are to determine the wavelength scaling for long-pulse laser breakdown thresholds in aerosols, the plasma growth rate scaling, and energy transmission.

The experimental arrangement that will be used is shown in Fig. I-1. The HF laser with the stable cavity has an output beam 5-1/2 in. in diameter with a beam divergence ≃10 mrad. Pulse energies as high as 250 J in 3 μsec can be obtained. The beam will be focused in an aerosol cell and recollimated with 6-in.-diameter lenses (GE 125 or Ca F_2). Beam splitters will be used to obtain energy and pulse shape before and after the breakdown region. The beam profile in the focal plane will be measured with a 64-element pyroelectric array. Photodiodes will be used to measure the time of onset of breakdown and the two-frame image-converter camera system will be used to obtain time-resolved information on the plasma growth rates.

The smallest focal spot is obtained with a focal length ≃12 in. For smaller focal lengths, the spot size increases due to spherical aberrations. Thus, the highest intensity expected is $\simeq 10^9$ W/cm^2. Although this is well below the clean-air breakdown limit for $\lambda = 2.8$ μm, it should be adequate for large particle induced breakdowns.

The experiment is tentatively scheduled for 12 to 30 July 1976.

D. E. Lencioni

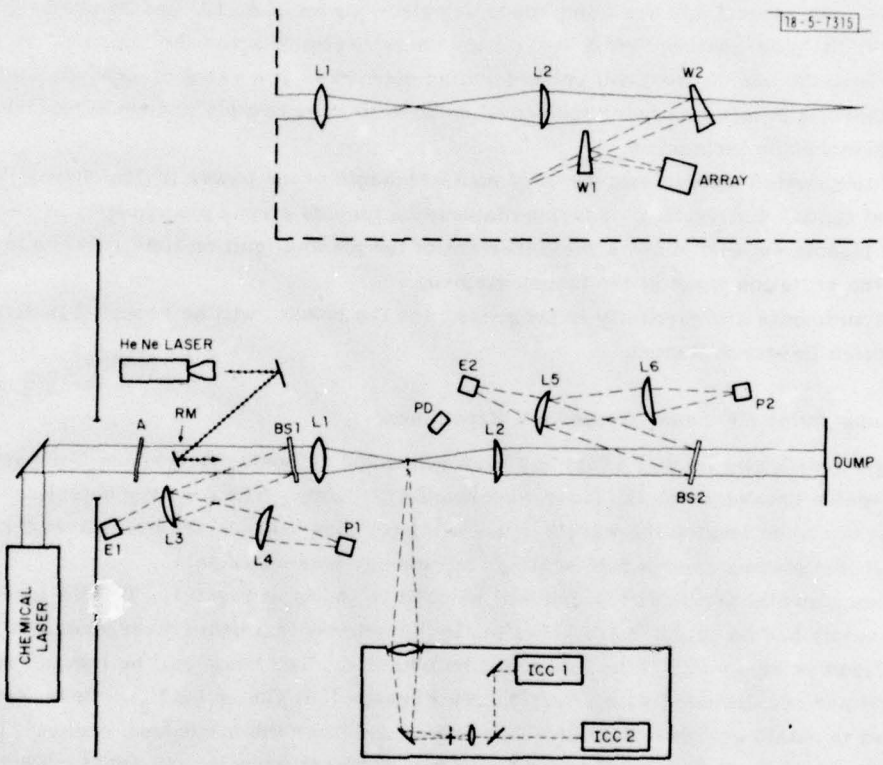

Fig. I-1. Experimental arrangement for long-pulse HF laser breakdown experiment. The insert shows the optical setup for the beam profile measurement.

B. STABLE CO_2 LASER DEVELOPMENT AND EVALUATION – CALIBRATION OF $^{14}C^{16}O_2$ LASER LINES*

We have recently achieved a significant advance in $^{14}C^{16}O_2$ laser operation and calibration. Although 12.1-μm operation was not difficult, the output mode was unusually bad and no $00^01 - [10^00,\ 02^00]_{II}$ band lines were observed. We now have definite proof that both of the above problems were caused by the poor imaging quality of the 12-μm gratings used in the two $^{14}C^{16}O_2$ lasers we built, even though both gratings had well over 90-percent efficiency in the first order at 12 μm.

After rebuilding one of the lasers using an older but superior 10-μm master grating, we obtained TEM_{ooq} mode operation in all four branches of the $00^01 - [10^00,\ 02^00]_I$ and $00^01 - [10^00,\ 02^00]_{II}$ vibrational bands and also in the $01^11 - 11^10$ "hot band." Figure I-2 shows the TEM_{ooq} mode output of the $^{14}C^{16}O_2$ laser operating at 12.1 μm.

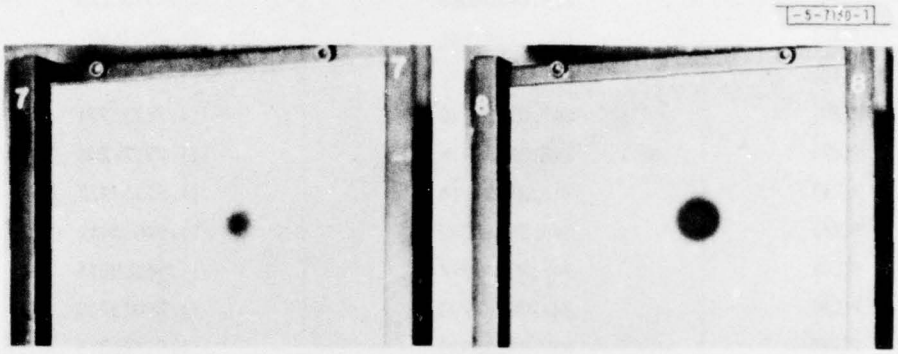

Fig. I-2. TEM_{ooq} mode output of $^{14}C^{16}O_2$ laser at 12.1 μm.

Tables I-1 to -4 list the $^{14}C^{16}O_2$ laser transitions we have measured with a 1-m SPEX grating spectrometer. Note, however, that the calibration of our spectrometer may be somewhat off at 12.1 μm. This discrepancy is probably due to the fact that our spectrometer calibration is based on CO_2 laser transitions between 9 and 11 μm, and linear extrapolation of these data to 12.1 μm may not be sufficiently accurate. However, the spectrometer data listed in Tables I-1 to -4 will soon be superseded by an absolute calibration (relative to the well-known $^{12}C^{16}O_2$ lines) of the $^{14}C^{16}O_2$ laser transitions by direct laser frequency heterodyne techniques.[1-3] As a matter of fact, Fig. I-3 shows the first direct beat frequency we have just obtained between the $^{12}C^{16}O_2$ $00^01 - [10^00,\ 02^00]_I$ band R(18) and the $^{14}C^{16}O_2$ $00^01 - [10^00,\ 02^00]_{II}$ band P(10) laser transitions. It is virtually certain that we shall obtain the absolute calibration (and final line assignments) of the $^{14}C^{16}O_2$ laser transitions within the next reporting period.

C. Freed

* This work was sponsored in part by the Defense Advanced Research Projects Agency and in part by the U. S. Energy Research Development Administration.

TABLE I-1

$00^01 - [10^00, 02^00]_1$ BAND TRANSITIONS OF $^{14}C^{16}O_2$ LASER

Transition	Vacuum Wave Number $1/\lambda$ (cm^{-1})	Vacuum Wavelength λ (μm)
P(2)	864.62063554	11.56576606
P(4)	863.04007227	11.58694749
P(6)	861.44323770	11.60842591
P(8)	859.83015375	11.63020389
P(10)	858.20083996	11.65228410
P(12)	856.55531342	11.67466928
P(14)	854.89358883	11.69736226
P(16)	853.21567846	11.72036597
P(18)	851.52159217	11.74368342
P(20)	849.81133740	11.76731771
P(22)	848.08491919	11.79127205
P(24)	846.34234015	11.81554972
P(26)	844.58360047	11.84015412
P(28)	842.80869794	11.86508875
P(30)	841.01762793	11.89035719
P(32)	839.21038339	11.91596315
P(34)	837.38695485	11.94191042
P(36)	835.54733044	11.96820292
P(38)	833.69149587	11.99484468
P(40)	831.81943442	12.02183982
P(42)	829.93112698	12.04919261
P(44)	828.02655200	12.07690741
P(46)	826.10568552	12.10498871
P(48)	824.16850119	12.13344114
P(50)	822.21497021	12.16226943
P(52)	820.24506138	12.19147846
P(54)	818.25874109	12.22107323
P(56)	816.25597330	12.25105889
P(58)	814.23671958	12.28144072
P(60)	812.20093905	12.31222413
Estimated Accuracy of the Spectrometer	±0.035 cm^{-1}	±0.0005 μm

TABLE I-2

$00^01 - [10^00, 02^00]_{II}$ BAND TRANSITIONS OF $^{14}C^{16}O_2$ LASER

Transition	Vacuum Wave Number $1/\lambda$ (cm^{-1})	Vacuum Wavelength λ (μm)
P(2)	981.11885429	10.19244504
P(4)	979.51363710	10.20914832
P(6)	977.87809045	10.22622359
P(8)	976.21227600	10.24367368
P(10)	974.51626743	10.26150136
P(12)	972.79015049	10.27970934
P(14)	971.03402292	10.29830033
P(16)	969.24799451	10.31727696
P(18)	967.43218707	10.33664182
P(20)	965.58673446	10.35639746
P(22)	963.71178255	10.37654637
P(24)	961.80748926	10.39709101
P(26)	959.87402451	10.41803377
P(28)	957.91157029	10.43937698
P(30)	955.92032059	10.46112295
P(32)	953.90048146	10.48327388
P(34)	951.85227094	10.50583195
P(36)	949.77591915	10.52879927
P(38)	947.67166819	10.55217786
P(40)	945.53977224	10.57596972
P(42)	943.38049747	10.60017673
P(44)	941.19412210	10.62480073
P(46)	938.98093639	10.64984348
P(48)	936.74124261	10.67530663
P(50)	934.47535508	10.70119179
P(52)	932.18360012	10.72750046
P(54)	929.86631613	10.75423405
P(56)	927.52385350	10.78139388
P(58)	925.15657465	10.80898118
P(60)	922.76485407	10.83699705
Estimated Accuracy of the Spectrometer	± 0.035 cm^{-1}	± 0.0005 μm

TABLE I-3

$00^01 - [10^00, 02^00]_1$ BAND TRANSITIONS OF $^{14}C^{16}O_2$ LASER

Transition	Vacuum Wave Number $1/\lambda$ (cm^{-1})	Vacuum Wavelength λ (μm)
R(0)	866.96091782	11.53454532
R(2)	868.50069101	11.51409562
R(4)	870.02409709	11.49393452
R(6)	871.53110327	11.47405980
R(8)	873.02167432	11.45446934
R(10)	874.49577261	11.43516105
R(12)	875.95335809	11.41613296
R(14)	877.39438828	11.39738313
R(16)	878.81881832	11.37890973
R(18)	880.22660091	11.36071097
R(20)	881.61768632	11.34278515
R(22)	882.99202244	11.32513063
R(24)	884.34955472	11.30774584
R(26)	885.69022621	11.29062928
R(28)	887.01397753	11.27377950
R(30)	888.32074689	11.25719515
R(32)	889.61047009	11.24087490
R(34)	890.88308052	11.22481751
R(36)	892.13850913	11.20902180
R(38)	893.37668448	11.19348666
R(40)	894.59753270	11.17821102
R(42)	895.80097752	11.16319389
R(44)	896.98694024	11.14843433
R(46)	898.15533974	11.13393147
R(48)	899.30609251	11.11968448
R(50)	900.43911259	11.10569261
R(52)	901.55431164	11.09195516
R(54)	902.65159889	11.07847149
R(56)	903.73088113	11.06524100
R(58)	904.79206279	11.05226318
R(60)	905.83504583	11.03953755
Estimated Accuracy of the Spectrometer	± 0.035 cm^{-1}	± 0.0005 μm

TABLE I-4

$00^01 - |10^00, 02^00|_{II}$ BAND TRANSITIONS OF $^{14}C^{16}O_2$ LASER

Transition	Vacuum Wave Number $1/\lambda$ (cm^{-1})	Vacuum Wavelength λ (μm)
R(0)	983.46970705	10.16808136
R(2)	984.99890975	10.15229550
R(4)	986.49766192	10.13687147
R(6)	987.96595602	10.12180626
R(8)	989.40379656	10.10709685
R(10)	990.81120009	10.09274017
R(12)	992.18819516	10.07873310
R(14)	993.53482238	10.06507248
R(16)	994.85113438	10.05175514
R(18)	996.13719581	10.03877783
R(20)	997.39308338	10.02613730
R(22)	998.61888580	10.01383024
R(24)	999.81470383	10.00185331
R(26)	1000.98065025	9.99020310
R(28)	1002.11684987	9.97887622
R(30)	1003.22343955	9.96786918
R(32)	1004.30056816	9.95717848
R(34)	1005.34839661	9.94680057
R(36)	1006.36709783	9.93673186
R(38)	1007.35685680	9.92696871
R(40)	1008.31787052	9.91750746
R(42)	1009.25034801	9.90834437
R(44)	1010.15451034	9.89947567
R(46)	1011.03059061	9.89089756
R(48)	1011.87883393	9.88260616
R(50)	1012.69949746	9.87459757
R(52)	1013.49285039	9.86686783
R(54)	1014.25917393	9.85941292
R(56)	1014.99876133	9.85222877
R(58)	1015.71191786	9.84531128
R(60)	1016.39896084	9.83865626
Estimated Accuracy of the Spectrometer	± 0.035 cm^{-1}	± 0.0005 μm

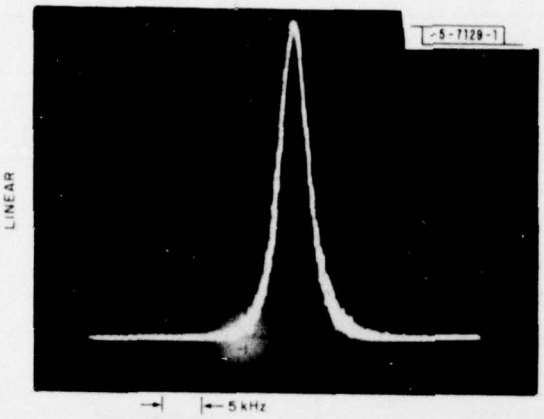

Fig. I-3. Beat frequency (3165 MHz) of a $^{12}C^{16}O_2$ 001-I band R(18) transition with a $^{14}C^{16}O_2$ laser line.

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2. F. R. Petersen, D. G. McDonald, J. D. Cupp, and B. L. Danielson, Phys. Rev. Lett. 31, 573 (1973).

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II. POLLUTION STUDIES*

Long-path monitoring of atmospheric carbon monoxide with high sensitivity and speed has recently been demonstrated using a tunable diode laser system.[1-4] We have made significant progress in improving the multipollutant capability and operating simplicity of this monitoring technique. The improved capabilities result from integrating a newly developed, widely tunable diode laser with a variable-temperature, stabilized, closed-cycle refrigerator. With this single source, it is possible to monitor any air pollutant whose absorption lines fall within bands of continuous tunability of the laser in the 9- to 12-μm region. The instrument also may be used to measure high-resolution (Doppler-limited) infrared spectra for line-strength calibration and identification of potential interferences. We illustrate its use for this purpose and estimate the monitoring sensitivity for several important pollutants, including ammonia, vinyl chloride, and ozone, based on laser spectroscopic measurements.

Tunable diode lasers are useful for long-path monitoring of air pollutants because their emission wavelengths can be made to coincide with infrared absorption lines of most gases, their output can be sufficiently collimated for transmission over distances of several kilometers, and they are readily adaptable to field use. Application of an individual laser to more than one pollutant, however, has been limited by a somewhat narrow tuning range ($\sim 30\ cm^{-1}$) and the need to maintain the diode at very low temperature (<20°K) for CW operation. A diode laser with significantly wider tunability was first developed in 1974 by Groves et al;[5] these lasers operated CW to a temperature of 80°K, with tuning over nearly 280 cm^{-1}. We have incorporated a new type of widely tunable diode lasers developed at Laser Analytics, Inc., which possess extended wavelength tunability (300 cm^{-1}) and operate CW at temperatures as high as 100°K. Significantly, these lasers produce radiation in the important 8- to 12-μm atmospheric window; and if liquid nitrogen is used to achieve operating temperature in a simpler (77°K) system, tuning over 100 cm^{-1} is still possible by varying the diode current.

Figure II-1 illustrates temperature tuning of a widely tunable diode laser with nominal frequencies for monitoring several pollutant gases indicated. It is apparent that strong absorption lines of many important gases fall within the overall tuning range of this laser, and it is worth noting that, with regard to long-path monitoring, atmospheric transmission over a 10-km sea-level path is typically greater than 50 percent throughout the 8.7- to 12-μm region,[6] making this an ideal spectral range for atmospheric long-path monitoring.

Figure II-2 illustrates application of the widely tunable laser, operating at a base temperature of 77°K in a liquid nitrogen dewar, in calibrating sensitivity species for a common pollutant, ethylene (C_2H_4). In this procedure, a pure sample of the pollutant is scanned with the laser, first at low pressure, then at atmospheric pressure using air or nitrogen for the balance. At low pressure, trace (b), the absorption lines are narrow and easily identified. Potential interferences from other constituents such as H_2O, CO_2, CH_4, etc., are identified by recording their low-pressure absorption lines in the same region. Wavelengths for monitoring are selected so as to avoid absorption lines of any interfering gases. Having selected the optimum monitoring wavelength, the atmospheric-pressure scan (c) then provides a quantitative measure of the attenuation coefficient per unit concentration. Relative frequency calibration is obtained by means of a Fabry-Perot étalon.[7]

*This work was supported by the National Science Foundation (RANN) and the U.S. Environmental Protection Agency.

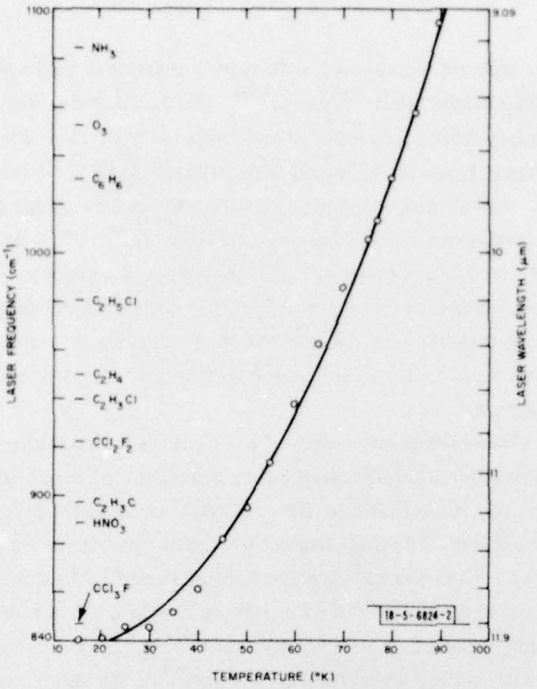

Fig. II-1. Temperature-tuning curve for widely tunable diode laser. Strongly absorbing regions for some common pollutant gases are indicated.

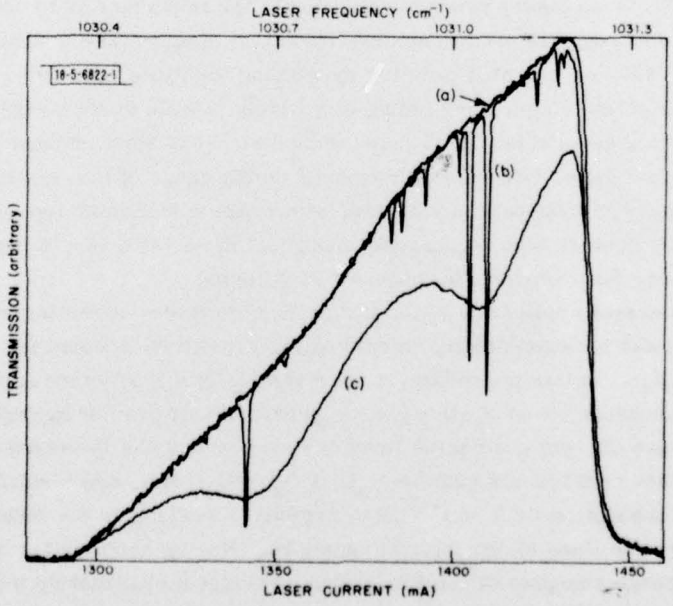

Fig. II-2. Laser spectroscopy of C_2H_4 using diode laser operating CW at 77°K (liquid-nitrogen-cooled). Trace (a) is for the evacuated cell, (b) for 1 Torr C_2H_4, and (c) for 13,200 ppm C_2H_4 in air at atmospheric pressure. Cell length = 30 cm.

Ammonia is another important gaseous pollutant in the troposphere and stratosphere for which sensitive monitoring instrumentation is urgently needed. Recently, Schnell and Fischer reported[8] spectrophone measurements of the absorption coefficients for NH_3 at several CO_2 laser lines, which included one of the highest values ever obtained in the infrared: 120 atm^{-1} cm^{-1} at 360-Torr total pressure, for the R(30) CO_2 laser line at 1084.635 cm^{-1} (~9.22 μm). Because of the interest in detecting this pollutant by laser techniques, we have examined in detail the NH_3 absorption in this region with the widely tunable diode laser of Fig. II-1 and with a grating-tuned CO_2 laser.* The resulting measurements are shown in Fig. II-3. Trace (a) is a

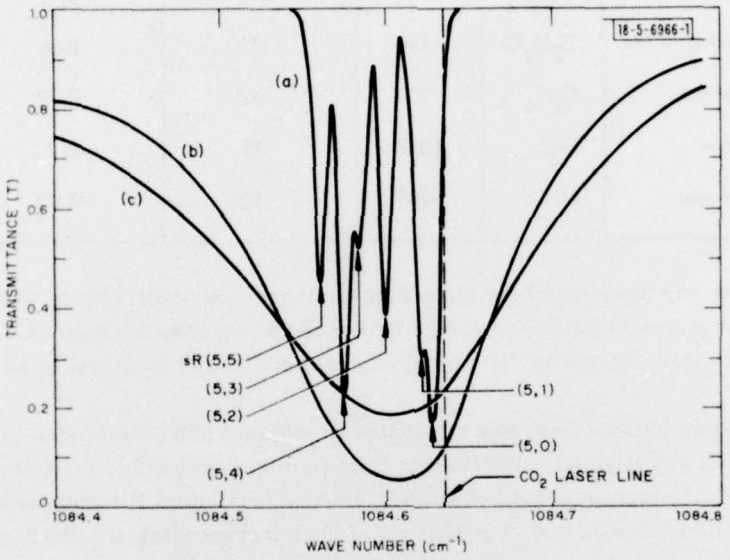

Fig. II-3. Laser spectroscopy of NH_3 using diode laser in closed-cycle refrigerator, operating at approximately 90°K. Trace (a) represents 1 Torr NH_3, (b) is 0.46 Torr NH_3 with 360 Torr air added, and (c) is 0.46 Torr NH_3 with 750 Torr (1 atm) air added. The CO_2 laser line is R(30) at 1084.635 cm^{-1}. Cell length = 30 cm.

diode laser scan of the pure gas at 1-Torr pressure, which reveals absorption lines corresponding to the six $sR(5, 0)$ to $sR(5, 5)$ NH_3 transitions listed by Garing, Nielsen, and Rao.[9] As far as we know, these lines have not been previously resolved. Trace (b) is a diode laser scan for 0.46 Torr NH_3 in 360 Torr air. The absorption coefficient at the R(30) CO_2 laser line was found, by using the discretely tunable CO_2 laser, to be 120 ± 10 atm^{-1} cm^{-1}, in agreement with Schnell and Fischer's measurement.[8] At line center (ν = 1084.605 ± 0.002 cm^{-1}, determined by correlating the CO_2 laser data and diode laser scans), the absorption coefficient is 162 atm^{-1} cm^{-1}. A total pressure of 360 Torr corresponds to an altitude of 5 km above sea level. Schnell and Fischer did not report any measurements for atmospheric pressure; consequently, we performed the laser scan of Fig. II-3(c) and also measured the absorption coefficient for NH_3 at atmospheric pressure for the R(30) CO_2 laser line. The absorption coefficient at the R(30) line is 75 atm^{-1} cm^{-1}, vs 93 atm^{-1} cm^{-1} at line center. Thus, the widely

* We are indebted to C. Freed for use of his CO_2 laser apparatus.

TABLE II-1

SPECTRAL ABSORPTION COEFFICIENT (k) AND PREDICTED SENSITIVITY FOR MEASUREMENT OVER A 1-km ATMOSPHERIC PATH FOR SEVERAL POLLUTANT GASES AT THE INDICATED FREQUENCIES (ν)

Molecule	Formula	ν (cm^{-1})	k ($atm^{-1}\ cm^{-1}$)	Sensitivity (ppb)
"Freon"-11	CCl_3F	847	110	0.27
"Freon"-12	CCl_2F_2	921	275	0.11
Vinyl chloride	C_2H_3Cl	940	11	2.8
Ethylene	C_2H_4	950	42	0.71
Ozone	O_3	1052	22	1.3
Ammonia	NH_3	1085	93	0.33

tunable diode laser has been useful for observing the transitions contributing to a strong absorption line of NH_3 at atmospheric pressure and revealing the relative location of a fixed-frequency laser line which appears attractive for monitoring this gas at sea level and to altitudes of several kilometers.

Using this widely tunable diode laser mounted in a temperature-stabilized closed-cycle refrigerator, we have investigated several other important molecular species listed in Table II-1. This table contains the largest values of atmospheric absorption coefficients measured for these gases at the indicated frequencies. Predictions of the corresponding sensitivities for a 1-km path are based on a state-of-the-art signal-processing capability.[1]

R. T. Ku
E. D. Hinkley

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This report covers work of the Optics Division at Lincoln Laboratory for the period 1 January through 30 June 1976. The topics covered are laser technology and propagation and pollution studies.

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